

# A Design for Affordances Framework for Product Packaging: Food Packaging Case Study

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## ABSTRACT

*Since affordances provided by packaging features play a major role in facilitating user packaging interaction, it is important to integrate the concept of affordances into the packaging design process and to understand the interrelationships between packaging features and affordances. A framework is proposed for linking user requirements to packaging design features utilizing the concept of affordances. The framework is accomplished in two main steps; first, determine the affordances required to facilitate performing packaging-related tasks, and second, link these affordances to packaging features. Previous packaging usability studies were reviewed to elicit requirements in terms of affordance properties such as intuitiveness, responsiveness, and clarity of information. The elicited properties represent the affordances of purchase-ability, store-ability, open-ability, reopen/reclose-ability, handle-ability, unpack-ability, and dispose-ability. An affordance structure matrix (ASM) was built to link user requirements, represented by affordance properties, to packaging features, and to appraise the links between them. To demonstrate its functionality, the framework was applied to assessment of a food packaging design. Further, a usability study conducted with 37 users agreed with the framework outcomes. The framework systematically incorporates user requirements for affordances into the design stage, thereby allowing modifications of packaging features to improve packaging designs based on affordance measures.*

## KEY WORDS

*Packaging, Affordance, Usability, Design, Framework*

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## INTRODUCTION

Product packaging is a growing global industry that supports logistical and marketing functions of business. It at present is unlikely to find products without packaging because of packaging's role in supporting a product supply chain and providing end users with protected and safe products. Packaging is perceived as an added-value element of products, even though it may contribute considerably to a product's cost. Roles of packaging have evolved as a response to evolutionary changes in manufacturing technologies, regulations, and lifestyles. In general, an ideal package should contain, protect, transport, and market products [1, 2], while presenting no significant usability difficulties.

The life cycle of product packages is comprised of several different phases determined by the product's nature. Users are expected to be involved with these packages and perform specific tasks during these phases, including buying, opening, handling, and storing, and a user's perception may be affected by problems and difficulties experienced during these phases. User satisfaction can therefore be improved by suitable facilitation of the tasks performed during the product lifecycle.

A package is comprised of both physical and informational features [3] such as size, shape, color, brand, surface texture [4], typography, illustrations, graphics [5], materials, geometry, symbols, labels, and signs. Such features provide information about the contained product and can affect the ease of use during its life cycle. Specifically, the information conveyed by these features can determine user actions when interacting with packages.

In practical terms, interaction between users and packages can be characterized by four main elements: the user, the task to be performed, packaging features, and the information obtained from these features as follows [6]. To perform a specific task, users first observe information characterized

by various packaging features such as size, shape, labels, color, and warnings. This information is then used as input to senses such as vision, touch, and hearing, then processed and transformed into internal representations. After then, users begin to recognize and assign meanings to the transformed information; internal presentations are usually associated with perceived affordances stored in a user's long-term memory. The implications of using the packaging features are then compared to the intended user's task. Finally, users' thoughts are translated into actions to accomplish the intended task, with this cycle repeated till the task is performed.

Interaction can be described as a system comprised of a user who uses the information provided by different packaging features to perform specific tasks. Figure 1 represents the user packaging interaction model with main elements. It is clear that packaging features convey different messages about the contained product, and can guide users to use packages as envisioned by product designers, and that the suitability of the information provided by these features can determine the quality of the perceived affordances. Such features are therefore considered to be main drivers of users' actions and important determinants of packaging usability.

Designers strive to design a package that provides users with the requirements essential to facilitate the completion of their tasks. These requirements can be represented in terms of affordance properties (Table1) expressing the affordances provided by packaging features. A package has many features that can be manipulated; for instance, the transparency, shape, size, and material of the package can all be changed with possible impact on users. Changing these features should be based on user requirements, or else the design will probably not be suitable for them. A packaging design framework is thus required to ensure the existence of the features required to support user requirements.



Figure 1. An illustration of user packaging interaction model; based on [6]

This work proposes an affordance-based design framework for product packaging. It links packaging features to user requirements through associated affordance properties elicited from previous usability studies and further verified by experts. The proposed framework uses an affordance structure matrix (ASM) to construct the relationships between affordance properties and packaging features. The framework's effectiveness was demonstrated through a usability testing study conducted on a product packaging.

## RELATED WORK

While packaging design has evolved to help users overcome many difficulties experienced while performing different tasks, users still experience problems related to product packaging usability, including clarity, safety, visibility, and accessibility [7]. In fact, this type of negative experience has potential for affecting user satisfaction while performing such tasks [8].

Because of the potential impact of packaging usability on user satisfaction, a great deal of work has been directed toward its evaluation and

improvement. For example, a usability survey was used to evaluate product packages by considering opening, usage, and after-usage stages, with a scale used to quantitatively express user experience [9]. Universal design principles have also been used to ensure product packaging usability for different users. For example, flexible product packages were evaluated based on universal design principles such as delivery of information, ability to open, and package design [10]. A survey for affirming the conformance of package designs to universal design principles has also been proposed [11], and a usability survey was introduced to evaluate package usability [12].

While previous packaging usability studies have been able to evaluate packages at different stages of their life cycles, these methods do not indicate the root causes of usability problems nor do they provide systematic suggestions for improving packaging design. In general, while such studies may conclude that there are difficulties in opening, disposal, or unpacking, they usually provide insufficient detail regarding the features actually responsible for such problems.

Many frameworks have been proposed for improving the packaging design process. For example, a method has been introduced to match user capabilities to packaging design variables while adequately maintaining basic packaging functions [13]. Furthermore, an optimization approach was applied to finding an optimal alternative packaging design among many alternatives generated through users' collaborations [14]. These studies established connections between packaging features and users' perceptions and accessibility, even though the connection between these features and the other aspects of packaging usability requires more attention.

In general, the aforementioned work can be divided into packaging usability and packaging design studies. Because usability studies focus on the interaction between users and packages with little effort applied to establish connections between packaging features and usability, they have been limited in capability for identifying the responsibility of different packaging features with respect to usability problems. On the other hand, previous packaging design studies have focused on aspects of accessibility and connections established mainly between packaging features and ability to open packages. Accordingly, there is a necessity to link aspects of packaging usability to packaging features to achieve a better understanding of potential improvements in packaging design. The concept of affordances can be utilized to construct this link and trace usability problems to particular packaging features. A design methodology has been proposed to ensure the existence of required affordances when considering packaging design [15].

One approach to improve packaging usability is to understand the affordances provided by packaging features [16], since these affordances are strongly related to usability [17]. "The term affordance refers to the perceived and actual properties that determine just how the thing could possibly be used" [18], and it can be expressed by a word ending

in ability [19]. In practice, it is hard to convey the meaning of the term affordance, although typical affordance properties, including intuitiveness, responsiveness, and information clarity can be used to express affordances [20].

Designers have utilized affordances to improve different products' usability. For example, usability evaluation has been used to study the effect of affordance quality on user-product interaction [21] and various methods have been introduced for affordance documentation and evaluation [22]. An online evaluation model reflecting the importance of affordance properties was also introduced to evaluate affordances associated with a product [20]. A design for affordance framework was also developed to ensure that design features provide the affordances required to facilitate interaction between users and products [23].

To utilize the concept of affordance, a mapping tool connecting affordances to packaging features should be utilized. An affordance structure matrix (ASM), an extension of a design structure matrix (DSM), can link requirements presented as affordances to physical features [22]. ASM represents an affordance-based tool in which affordances depend on design features, allowing designers to identify relationships between affordances and features [24, 25]. An ASM specifically correlates design features with affordances and allows designers make comparisons between designs using the links between features and affordances [26]. Each feature considered in the ASM can be described as being positively, negatively, or not affecting each affordance [24, 27]. To build an ASM, user requirements should be translated into affordances that in turn may be affected by features [28].

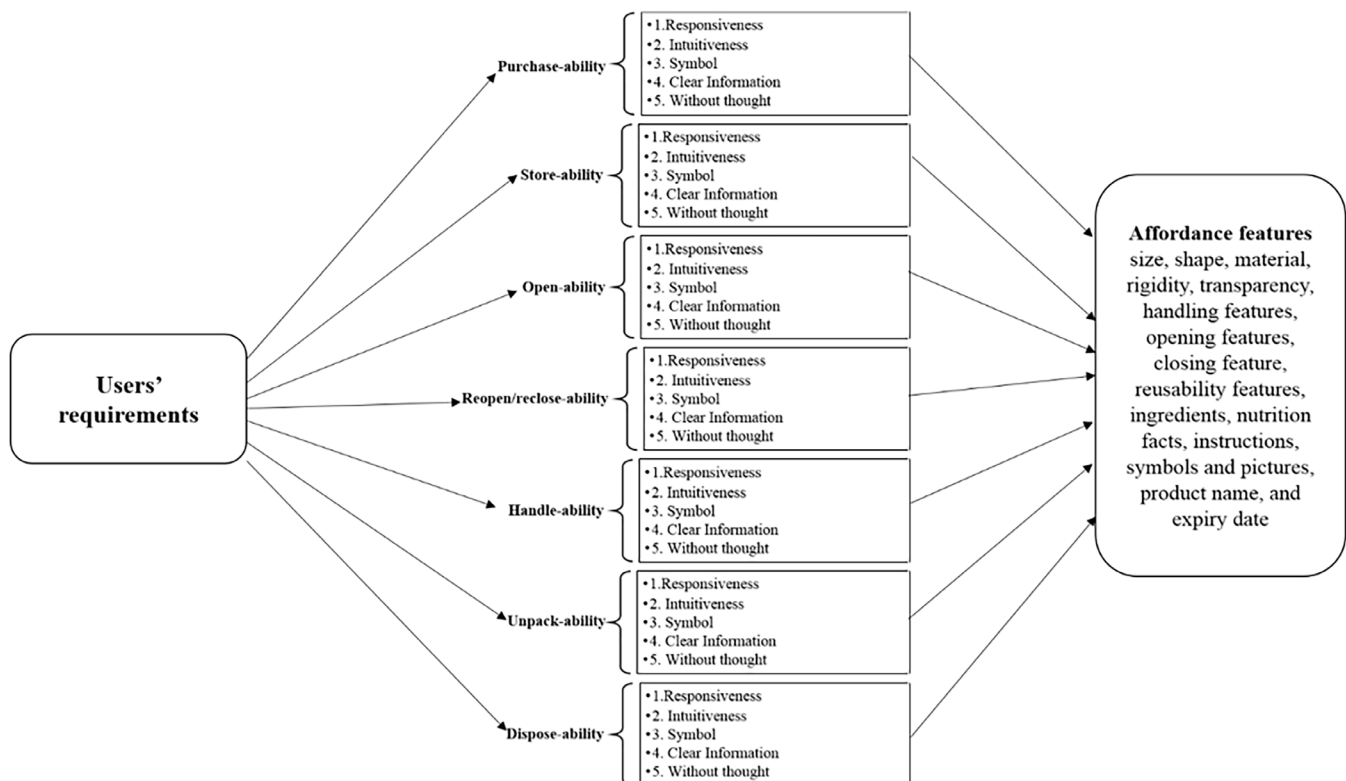
This work proposes a design framework for helping designers improve packaging usability through the concept of affordances. The proposed framework can be incorporated into the design process of product packaging. Specifically, by

supporting systematic incorporation of users' requirements and determination of relationships between packaging features and affordances. Accordingly, modifications on packaging features can be performed during the packaging design phase by evaluating their effects on the affordances. Overall, this paper tries to make the packaging design process more systematic and provide the advantage of considering different aspects of packaging at early design stages.

## METHODOLOGY

The proposed framework utilizes the concept of affordance to map users' requirements to packaging features. The overall structure of the proposed framework allows an affordance driven package design through linking users' requirements for affordances and packaging features, as shown in Figure 2.

Generally, there is a wide variety of user requirements rooted from the fact that products vary in terms of types, users, characteristics, and usage. These variations in user requirements reduce or eliminate the possibility of designing packages based on the same set of requirements, complicating the packaging design task, so providing the packaging community with a generic design framework that can be applied to different packaging types is required. To this end, affordance properties can be



elicited from generic user requirements and further verified to suit particular packages.

## DESIGN FRAMEWORK

The design framework can be outlined in five steps; eliciting affordance properties, selecting a product of interest, affordance features identification, building an ASM, and calculating metrics.

### Eliciting affordance properties

The first step of the framework is to elicit affordance properties from user requirements. To do so, packaging usability studies were surveyed to obtain user requirements, producing about two hundred requirements [7, 9-12, 16]. These requirements were reviewed and then combined, based on their similarities, into thirty-eight distinct requirements. These requirements were then associated with the five basic affordance properties [20] as shown in Table 1. The elicited properties express affordances related to the tasks of purchasing, storing, opening, unpacking, reclosing, handling, and disposing of packages.

### Selecting product of interest

The proposed framework can be applied to different products because it relies on the same initial set of user requirements. Once particular product is selected, the context of use, tasks performed by users, and product characteristics should be enumerated to determine the requirements from the initial set that should be considered.

### Affordance features identification

Packaging features providing affordances are called affordance features [23]. These features can be classified into physical and verbal features. The physical features can be in form of size, shape, material, rigidity, transparency, handling features, opening features, closing features and reusability features. The verbal features can be represented by ingredients, nutrition facts, instructions, symbols and pictures, product name, and expiration date. These features convey information about the product/package throughout its lifecycle and guide users in performing packaging related tasks. Features associated with one affordance property at least are considered to be affordance features with potential impact on the corresponding properties,

*Table 1. Affordance properties related to open-ability.*

Elicited Requirements	Associated affordance property
The package helps me to pay attention during opening tasks.	Without thought
Can understand how to open the package correctly without reading the opening instructions.	Intuitiveness
Symbols and pictures related to the opening task are helpful and comprehensible.	Symbols
Find the opening position and instructions easily.	Responsiveness
Opening instructions and methods are obvious.	Clear Information



and such associations can be constructed based on observational studies [15].

### Building an ASM

The ASM concept can be utilized in constructing the link between packaging features and affordance properties. ASM helps in systematically defining relationships between features and affordance properties. The main components of an ASM are affordance properties (in the rows), affordance features (in the columns), and relationships between affordances and features (the interior elements of the matrix). Three types of relationships between the affordance properties and features can be defined in ASM, i.e., helpful (+1), harmful (-1), or no relationship (0) [24]. Table 2 shows the basic components of an ASM that can be used for product packaging design.

### Calculations

Different evaluation metrics can be extracted from the ASM to evaluate relationships between affordance properties and their related features. The total number of helpful and harmful features with respect to a particular property, the total number of properties for which a feature has helpful or harmful relationships, and the percentage differences are considered the basic metrics [24].

In this framework, each affordance is presented by the term  $A_i$ ,  $i=1, \dots, I$ . An affordance property related to affordance  $A_i$  is represented by

$p_{im}$ ,  $m=1, \dots, M$ . A packaging feature with a relationship to a property  $p_{im}$  is represented by  $F_{imk}$ ,  $k=1, \dots, K$ . This relationship can be represented by the term  $X_{imk}$  as follows:

$$X_{imk} = \begin{cases} -1, & \text{if feature } F_{imk} \text{ doesn't support property } p_{im} \\ 0, & \text{if feature } F_{imk} \text{ is not related to property } p_{im} \\ 1, & \text{if feature } F_{imk} \text{ supports property } p_{im} \end{cases}$$

The package under study can be evaluated according to its ability to support the required properties through use of different packaging features. The features related to affordance properties are assigned scores according to the following rules: if the package has the feature and supports a property, it is assigned a score of (1). If the package has the feature and does not support the property, a score of (-1) is assigned. If a package lacks a feature required to support an affordance property, a score of (-1) is also assigned.

For each affordance property, the percentage difference can be calculated using Equation 1. The percentage difference of an affordance can be calculated using Equation 2, while Equation 3 can be used to calculate the overall percentage difference of the packaging design. The percentage difference of a feature can be calculated as shown in Equation 4. The highest possible value of these metrics, 100%, represents the ideal case in which no packaging design modifications are required since the affordance properties will be fully supported by the related features.

Table 2. ASM structure; updated from [24]

Affordance	Properties	$F_{im1}$	$F_{im2}$	$F_{im3}$	$F_{imK}$	Total harmful	Total helpful	Total	Percentage harmful	Percentage helpful	Percentage difference
$A_i$	$P_{11}$										
	$P_{12}$										
	$P_{13}$										
	$P_{1M}$										

The resulting scores can be considered as measures of the gap between a current and an ideal packaging design [24]. Affordances with scores greater than 0% and less than 100% indicate that the corresponding affordance features have more positive than negative relationships. Affordances with a 100% score are considered to be satisfied with no need for further modification of the associated affordance features. A score  $< 0\%$  for an affordance indicates that the corresponding features have more negative than positive relationships. Features with low percentage difference scores do not support the related affordance properties in a proper manner. To improve the affordance scores, the features with negative relationships should be reviewed and modified.

## CASE STUDY: FLOUR PACKAGE

This framework was applied to food packaging due to the fact that users are in daily contact with food packaging which accounts for most of the packaged products [9]. In particular, 2.27 kg Flour packages were examined by focusing on the link between packaging features and affordance properties. Four experts with human factors and other expertise were invited to participate in an experimental session where they were asked to verify the initial set of affordance properties to ensure their suitability for flour products. The experts selected 27 affordance properties from the 38 comprising the initial set of properties as shown in Table 3.

Thirty-seven participants, 22 females and 15 males, all age 18 or older, participated in a controlled usability experiment. They were asked to perform specific tasks to simulate normal interaction during the product life cycle. These tasks included purchasing, storing, opening, unpacking, reclosing, handling, and disposing of flour packages consisting of a folded paper bag and a plastic dispenser as shown in Figure 3. The packages were

introduced to the participants in a counterbalanced manner to ensure experimental randomization. The participants were observed while performing the aforementioned tasks to determine interrelationships between affordance properties and packaging features. Fifteen packaging features were identified and associated with affordance properties. After identifying the affordance properties and their associated affordance features, the ASM was constructed. Features related to each affordance property were appraised according to their ability to support that property.



A folded paper bag  
Dimensions : 15.7\*10.9\*22.1 cm  
Weight (kg): 2.27 kg



A plastic dispenser  
Dimensions: 18.5\*13\*25.5 cm  
Weight (kg): 2.27 kg

Figure 3. Flour packages; Package 1(left) and Package 2 (right).

For some affordance properties, association with particular affordance features was clear. For example, to facilitate the task of purchasing, the quantity in the package should be determined and visibly identifiable, and package transparency, size and information are affordance features that affect the property “Responsiveness” associated with this requirement. For other properties, the affordance features were identified based on user actions and common-sense reasoning. For example, to perform the task of opening, users



had to grasp the package and find and utilize an opening feature. The size, shape, rigidity, and handling features induce a grasping action, while material and opening instructions and features induce the action of opening. Just as for the after-usage stage, the size, shape, material, rigidity, after usage, and instructions features affect user

actions when dealing with empty packages. These features were associated with the corresponding affordance properties and the packaging evaluations were based on the determined relationships.

The results of the ASM reflected some issues with Package 1. It didn't fully satisfy the affordances where all recorded negative percentage

Table 3. Elicited requirements with their associated affordance properties

Elicited requirements	Associated Affordance
<i>Purchasing</i>	<i>Purchase-ability</i>
The quantity in the package can be determined and visible.	Responsiveness
Handle the product properly without reading instructions.	Intuitiveness
Find the important information; product descriptions, expiry date, nutrition facts, warnings, etc.	Responsiveness
The information listed on the package is understandable and readable.	Clear Information
Can understand how to use the product properly without instructions.	Intuitiveness
<i>Storing</i>	<i>Store-ability</i>
Find the storage instructions and check the expiry date immediately.	Responsiveness
Know the current level of the contained product, "visibility".	Responsiveness
Can understand how to store this product without reading storage instructions	Intuitiveness
The package helps me to pay attention during storing tasks	Without thought
<i>Opening</i>	<i>Open-ability</i>
Find the opening position and instructions easily.	Responsiveness
Opening instructions and methods are obvious.	Clear Information
Can understand how to open the package correctly without reading the opening instructions.	Intuitiveness
<i>Reopening/reclosing</i>	<i>Reopen/reclose-ability</i>
The package helps me to pay attention during reopening/reclosing.	Without thought
Can understand the reopening/reclosing methods without reading instructions.	Intuitiveness
Find the reopening/reclosing features immediately.	Responsiveness
Reopening/reclosing instructions and methods are obvious.	Clear Information
<i>Handling</i>	<i>Handle-ability</i>
Can understand how to handle the package without reading handling instructions.	Intuitiveness
Symbols and pictures related to handling are helpful and comprehensible.	Symbols
The handling features can be found immediately	Responsiveness
Handling instructions are obvious	Clear Information
<i>Unpacking</i>	<i>Unpack-ability</i>
Can understand how to unpack/use the product without reading instructions	Intuitiveness
The unpacking features can be found immediately	Responsiveness
Symbols and pictures related to using/unpacking the product are helpful and comprehensible.	Symbols
Know the current level of the contained product, "visibility" and how much did I take from inside the package	Responsiveness
<i>Disposing</i>	<i>Dispose-ability</i>
Segregation, disposal, and recycle instructions, and reuse options are obvious	Clear information
The disposal, recycle, segregation, and reuse related features can be found immediately	Responsiveness
Can understand how to dispose, segregate, recycle, or reuse the package correctly without reading the related instructions.	Intuitiveness

differences with exception for purchase-ability, open-ability, and dispose-ability. The ASM specifically showed that many features such as transparency, handling, reclosing, and information and instruction were associated with negative difference percentages. Improving features with such negative relationships is expected to help recovering the related affordances. This indicates a need for package redesign to ensure the existence of the required positive relationships.

An ASM was built for Package 2 to determine the effect on the percentage difference scores of having a package with different characteristics. The results showed that Package 2 satisfied most of the affordance properties and, as shown in Figure 4, achieved positive scores for all affordances. Since

it has good transparency, handling, after usage, and reclosing features, as well as information, this package supports the affordance properties with the required features, making this package differ from Package 1. The overall percentage differences of the two packages were also calculated, with results showing the superiority of Package 2, with a score of 83%, compared to the 10% score of Package 1.

After performing each of the tasks, the users were asked to respond to a statement about the ease of interaction with the package. In general, the statement was in the form of “It was easy for me to know and understand how to (Task) the product/package. A seven-point Likert scale was utilized to express the level of agreement with the provided statements, with 1 being strongly disagree and 7 strongly agree.

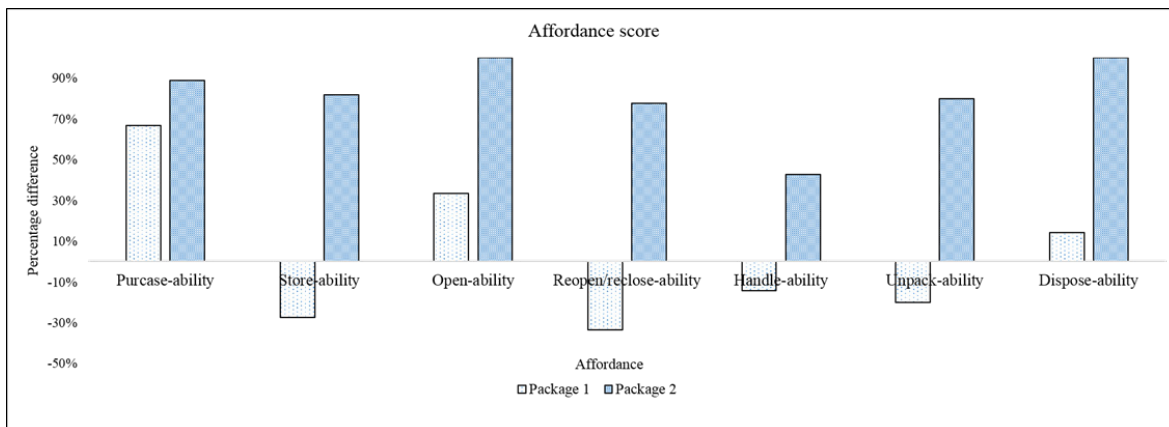


Figure 4. Results of the ASM

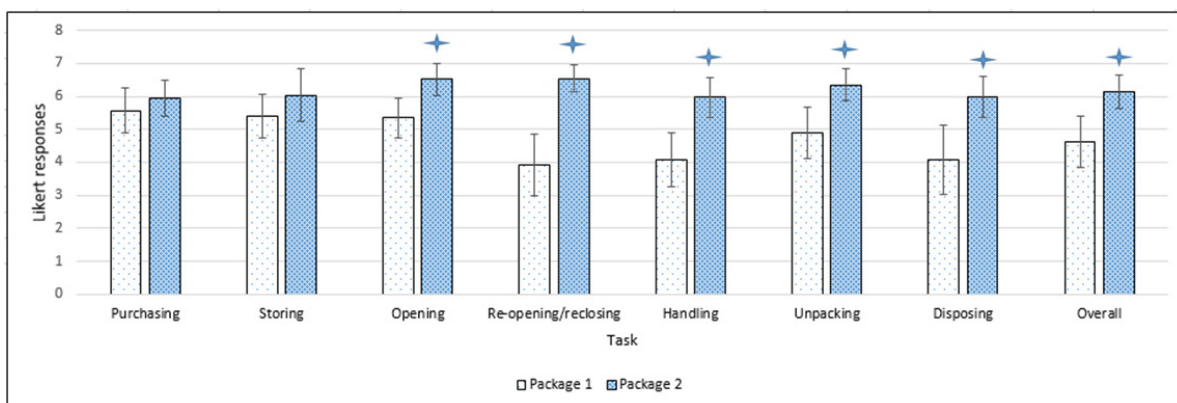


Figure 5. Results of the evaluation of the packages under study.  $N=37$ , except for the overall measure  $=36$ . (  $P$ -value  $< 0.05$ )

A paired t-test was used to examine the significance of the differences between the scores of the two packages, and the results showed that the scores of Package 2 were significantly higher than that of Package 1 with respect to the tasks of opening, reopening/reclosing, handling, unpacking, and disposal. Participants were also asked to respond to a statement about the overall design of the package. Package 2 achieved a significantly higher number of Likert scale points, as shown in Figure 5, a superior result explained by Package 2 being perceived as more informative than Package 1.

### Limitations

Although the case study was a simulation study in which participants did not perform the whole range of tasks of purchasing, unpacking, storing, and disposing, this was not found to significantly affect the results since the focus was on the affordances and the information provided by the packages and not ability to perform the actual tasks. Affordance features of any particular property were assumed to have the same importance to that property and a simple scale was used to evaluate relationships. This seemed reasonable because the framework was meant to be attention-directing tool.

## DISCUSSION

This paper proposed a design framework based on the fact that affordances are dependent on design features. The framework was developed to help designers apply modifications during the design stage, with subsequent consideration of the potential effects of such modifications on packaging affordances. The framework was demonstrated using a Flour product in a case study. Two Flour packages were appraised with respect to the ability of their features to support the required affordance properties. The framework facilitated the identification of packaging features needing modification to improve affordances.

The results showed the superiority of Package 2 over Package 1 because it satisfied most of the required affordance properties through the flour product life cycle. In general, Package 2 outperformed Package 1 because of its transparency, rigidity, handling, reclosing, and reusability features, and its superior instructions. The usability testing study, wherein Package 2 obtained more Likert scale points than Package 1 with respect to different tasks, supported the framework's results. Overall, Package 2 was perceived to be significantly better than Package 1.

The ASM showed that more relationships than those only resulting from verbal features were specified between affordance properties and physical packaging features, indicating the potential impact of physical features on packaging affordances for this particular product. The features associated with the largest number of affordance properties were information and instructions, size, transparency, rigidity, shape, material, handling, and opening features. These features should be considered critical to the packaging design process of the Flour product because of their significant impact on many affordance properties. More efforts should be directed toward ensuring the suitability of such features at the design stage. The lack of such features will have significant negative impact on the affordances provided by the package, while features with no significant impact on affordance properties can be considered noncritical with respect to the affordances provided by the package.

The ASM visualizes the relationships between the required affordance properties and packaging features and it can locate problems of packaging design that lead to low affordance scores. For example, Package 1 has a low open-ability score and this could be explained by the low percentage of difference recorded for the properties related to ability to understand how to open the package without instructions, i.e., "Intuitiveness", and those related

to finding and comprehending the opening instructions, i.e., “Responsiveness and Clear information”. Features related to these properties with negative relationships should also be reviewed. For example, Package 1 lacks a handling feature and opening instructions and information, resulting in negative relationships. Providing these features would improve the percentage difference of the associated properties as well as the open-ability score.

## CONCLUSION

This paper describes construction of a design framework based on a user packaging interaction model. The framework was developed to allow affordances-driven design that takes into account requirements for affordance properties. A food-packaging design case study was introduced to illustrate the functionality of the framework. Two packages were presented to show how packages with different features will produce different affordance scores. According to the framework, Package 2 has higher affordance scores than Package 1, and this rating was supported by the higher Likert scale responses obtained from the participants in the usability study. Package 2 supported the required affordance properties, and it was perceived to be more informative than Package 1; it provided the users with information required to perform the tasks considered in the study.

Applying this framework will help a designer understand relationships between packaging features and affordances and receive early feedback about a design. Expressing the affordances in terms of affordance properties facilitated associations between affordances and features, helping in building the connections between affordance features and properties at early stages of a packaging design.

ASM utilization has the advantage of supporting the visualization of relationships between user requirements for affordances and packaging

features, and it can also be used to appraise packaging designs with respect to their ability to support required affordance properties through packaging features. Application of the framework provides insights into possible roadmaps for improvement guided by affordance scores and the links between affordances and packaging features.

The framework is an attention-directing tool for locating problems that should be fixed. It can be used to create alternative packaging designs through understanding of affordance properties and their associated features. It focuses on affordances, embracing the different types of information provided by a package. Given the importance of providing a user-friendly package, the physical capabilities of users should also be integrated into the framework to ensure that users understand how to deal with their packages, and are capable of performing the required physical actions. The framework is suitable for use by packaging designers in designing various product packages, e.g., for medications. The cost of packaging was not considered in this framework, and in future work packaging cost could be introduced as an additional metric for evaluating packaging designs. More consideration should also be directed toward understanding the effect on other properties of supporting a particular property.

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